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ABSTRACT

Use of computers for individualized instruction will bring about some new roles for what we now call teachers. In turn, these new roles will have many implications for colleges of education which must prepare teachers for these roles. In addition to master teachers, instructional managers, operations technicians, librarians, and proctors, a key role will be that of the instructional designer, who will write materials to store in computers or other self-instructional systems of the resource center. The model of instructional design used at the University of Texas Computer Assisted Instruction Laboratory includes five steps: outlining needs, goals, and a justification; developing the design architecture and rationale; writing an author's draft; producing a computer program; and evaluating the course. This method is exemplified by a design for teaching written Arabic and is considered a metaphorical representation of systems analysis. Cross-fertilization of disciplines (computer science and educational research) should provide advances in course content, course organization, and instructional methods. (JK)

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INSTRUCTIONAL DESIGN, COMPUTERS, AND TEACHER EDUCATION

TECHNICAL MEMO NO. 2

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P R E F A C E

One of the goals of The University of Texas/National Science Foundation Program, *Foundations of Instructional Design for Computer-Based Systems*, has been to expand the findings of instructional research into academic programs in colleges of education. Computer-assisted instruction (CAI) and the emerging technology of instructional design have important implications for the organization, administration, content and outcome of teacher education programs.

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Richard Heming, one of the participants of this conference, has warned us not to expect any "level of magnitude" increase in effectiveness due to computers. The purpose of this paper is to present propositions different from Heming's by defending an alternate thesis concerning a statement by Arthur Koestler (1964):

> *All decisive advances in the history of human thought have come about as a result of mental cross-fertilization between different disciplines.*

Hybridization similar to this, in my opinion, will occur between computer science and educational research. The first proposition, then, is that a mental cross-fertilization will effect decisive advances in course content and organization, as well as instructional methods. This is, simply, a different approach to Heming's requirement that there be a level of magnitude improvement in effective delivery, because he states implicitly that the results of computer-assisted instruction and traditionally-administered instruction will be compared. In addition to the changes put forth in the first proposition, the management of the whole educational process will change. If this prediction is correct, a sheer comparison--a race between a horse and an early-model car, as Harold Mitzel, also a conference participant, described it--really does not apply. It will therefore be most difficult to determine the basis for calculating whether or not a level of magnitude improvement has taken place. Seidel (1969) has made this point elsewhere in reference to "cost-effectiveness" of CAI.

The second proposition is that the modes of organizing and staffing educational systems will change decisively because of computers and the kind of thinking they induce. These two propositions form the basis for this paper.

One View of Tomorrow's Schools

In order to motivate the discussion of the first proposition, a hypothetical educational system 20 years from now will be asserted. Some of the trends and ideas in current educational literature could lead to the conclusion that such an individualized system would be desirable and indeed necessary, but a justification will not be attempted here. For now,

it is sufficient to say that the need for some form of an individualized system is rooted in real societal problems. The quality and relevance of education for the individual must be increased, yet accomplished with greater efficiency in information transmission and with reduced cost-per-unit transmitted.

Therefore, assume now an individualized school of the future. By *individualized instruction* is meant continuous progress based on the individual student (although this does not preclude group activities). Objectives may be established differentially for individuals as well as pace and sequence. At first glance, this school most resembles a resource center. It might be a school by day and a library, computer, and media resource center by night for adult education and other forms of community activity. It would have

--CAI
--a library
--various kinds of media

and perhaps it would also have

--a dial-access information retrieval system
--a staff 20 hours a day

But whatever the components, a resource center would be the heart of it.

The hypothetical staff of *tomorrow's school* is given in Figure 1, listing some new roles for what are now called teachers. Some of these are minor modifications of current roles. Presently, there are master teachers here and there as well as people who are primarily engaged in the management of students, teachers, and resources. However, there are very few instructional designers, especially as defined in this discussion. These are the people who will be writing the materials to store in the computer and in the other self-instructional systems of the resource center and who will supervise production technicians. There are some of these today, as well as media specialists of various kinds and programmers.

Insert Figure 1 about here

The manager of individualized instruction has a different role. Perhaps the role for most of the teachers of today would evolve into this. It is more the model of a physician who desires to diagnose the needs of the students and prescribe the appropriate treatment. This person would, in his training, learn about computer-managed instructional systems, how to obtain data on students, and how to use this data in diagnosing and prescribing instructional activities. In order to make diagnoses and prescriptions, he would have to be familiar with the programs on the system in his school, what their objectives are, and what they could accomplish for students. He would also, of course, prescribe work with the teachers

in the system, or he would help design a plan of action in consort with these teachers. A current trend suggests that students themselves will share heavily in the processes of diagnoses and prescriptions.

This is a healthier model of the teacher than exists today. The teacher of today, if compared to the physician, would be placed in the position of saying

> *But, sir, when your child came to me with the educational problem you describe, I prescribed the treatment which works for the average student. The fact that he failed and may drop out and lose hundreds of thousands of dollars of income in his future life, perhaps going into crime, is not my fault. The "educational pill" I use for the average student was the only one I had available.*

Of course, the parent would not readily accept a statement of this kind if it came from a physician and would insist that he find another pill or treatment that would be effective. The instructional manager would be trying to emulate some good aspects of the physician's role.

Harold Mitzel reported earlier that one of the teachers in Appalachia who took his modern math program said, *"This [CAI experience] is the first time in years that I have been able to think."* Mitzel's reason for the teacher's statement was that teachers have so much pure management responsibility, discipline problems, and shuffling of textbooks and materials as to preclude study, even when the inclination is there. In the school of the future, an information management system based on the computer must be provided that handles most of the paper shuffling and grading and that, as a side benefit, removes many discipline problems. In the individually-prescribed instruction schools and some of the better individualized team-teaching environments, it is found that the students work happily. They are a bit noisy, granted, but because they are working on interesting problems, discipline becomes a minor issue. With a computer to manage the information flow and to record grades and student progress, the staff can be reduced without affecting control and management of information.

The instructional manager will be assisted by operations technicians, proctors, librarians, and computer operators. These people will perform much of the clerical and technical operational activities and, perhaps, will also be training to progress to a more responsible role, either as a manager, a teacher, or an instructional designer. There is a good ladder for inservice professional advancement in this system.

The fifth role listed in Figure 1 is that of master teacher. They are somewhat in the category of instructional designers in that there are very few of them, too few for today. There could be more if some of the responsibilities were removed from teachers for information transmission, lunch money, grading, record keeping, and discipline. The teachers could be trained far better than they are now. They should be well paid because they

are the ones who inspire, motivate, work with individuals, and provide a human, professional model for what a student could become in the field of expertise which that teacher represents.

Return now to this model of individualized education which, it is assumed, must come to pass. It *can* come to pass--whether or not it does depends on people's values and the effort they give to realizing it or defeating it. This can be made to come to pass or some other system could be made to come to pass. By default, current systems are allowed to degenerate to more undesirable systems, faced by today's enormous pressures.

Where will the people for these new roles come from? Who will educate them? For the role of manager, some advanced work is being done by Research for Better Schools, using the individually-prescribed instructional model. Everyone has his own model for the role of the master teacher. There will continue to be controversy over this, and some of it is good. A way is needed to define a master teacher according to the outcome of student behavior in terms of student growth, so that the teacher's advancement and salary become contingent upon socially desirable outcomes in the students.

Processes and Products of Instructional Design

The first two roles listed in Figure 1, those of instructional designer and his assistants, have been taken at The University of Texas Computer-Assisted Instruction Laboratory (CAI Lab) as one of the focal points. While all of the answers are not known about training the instructional designer, we think we have a few promising approaches. The following is a description of an instructional design procedure developed in the CAI Lab which provides a partial outline from which programs for instructional designers can be developed in colleges of education. Figure 2 is a partial representation of what the CAI Lab calls an *instructional design model* (Bunderson, in press). *Model* in the sense used here, merely means a representation of the instructional design process and its products. Design is represented as an interrelated set of activities and products. This representation allows communication with students and, thus, allows instructional design to be taught; it also allows instructional and learning research to be focused in such a way that the outcome can be made relevant to the instructional designer. This attacks a great deficiency in psychological research: *It has not been relevant to the human activity in instructional settings.* Now the instructional designer's role can be tied definitely to research because the products of his activity are reproducible and testable, whereas the products of the classroom teacher are very ephemeral and often based on personalities and subtleties in the interpersonal relationship. However, the instructional designer's products are tangible artifacts of intellect. They are objects whose effects can be tested, evaluated, and measured such that research can be focused upon them.

This instructional design model also focuses the computer system research at the CAI Lab so that developments can again be emphasized that will be useful to the humans who will staff the instructional systems of the

future. One area of research that is particularly relevant is design automation. Here, systems development is focused on those systems that will help people to use the computer easily, communicate with it more easily, and perhaps help them with certain aspects of the instructional design process. Instructional design is a costly and difficult process, and any assistance from the computer is greatly desired.

Finally, the last function of this instructional design model is to provide a management system for curriculum development. When a researcher has been involved in major, highly-expensive curriculum development efforts for CAI, under contract deadline for development with a publisher or other agency, it becomes necessary to provide a model different from that of the ivory-tower professor capable of working at his own pace. A management system is needed, and this model of instructional design permits work and activities to be scheduled and control to be maintained of being on schedule so that there are accomplishments. The intermediate products attained at the various checkpoints also permit the application of quality control procedures.

An overview of the model is provided in Figure 2. There are two columns, one headed *Activities* and the other headed *Products*. Basically, there are five classes of activities:

(1) The first is *outlining needs, goals, and a justification*. This concerns deciding what is going to be done and why. The products are in the form of proposals to funding agencies or--once the program is completed--brochures.

(2) The second activity is least taught and least available in the literature. It is the *development of the design architecture and rationale*. This consists of specifying performance objectives and analyzing them into a learning hierarchy or other structural representation.

(3) The individualizing mechanisms are then *selected and represented by flowcharts* which reveal the different options the students will have within an individualized CAI program under program control or learner selection.

(4) The fourth activity is that *display and response conventions are established* by examining each subobjective and knowing that, as a good performance, it has two principal parts: (a) the materials given or displayed to the student, and (b) the task required of the student. The materials specify in some way the program displays. For example, consider the objective: Given spoken Russian words, the student will type in the English equivalents. This specifies that there must be some type of audio system on the computer as well as a keyboard for response entry. Every adequate objective

has the following aspects: (a) it specifies the display and response conditions broadly (at least for the terminal parts of the sequence related to that objective); (b) the designer must define display and response conventions and render them operational in terms of some particular system. He must also decide upon some restrictions that he will live with in writing the program.

After decisions have been made concerning the hierarchy, the architecture of the program, the flow, and the conventions that will be used for each sublesson, the designer can write a manuscript or author's draft. This is used by the media specialists and programmers to produce the program.

(5) The fifth major step in Figure 2 is *to subject the produced program to formative and summative evaluation.* Any part of the total process might recycle.

There is, in fact, a great deal of recycling and iteration throughout the design process. This recycling could better be represented with a flowchart, but tabular representation of design activities seems to be a better communication medium for most audiences than is a flowchart. In Figure 2, the flow is basically from top to bottom although there may be many loops back to an earlier point. For example, having completed the learning hierarchy, one may wish to revise the previously-stated prerequisites on the basis of this more precise analysis. The production activity, due to the interaction between programmers, media specialists, and author-designers, is a great source of stimulation to revise earlier design products. The major source of stimulation for revision, of course, comes from students who take the first version of the program. The analysis of the student responses, difficulties, and observations leads to healthy revisions. It is a prime characteristic of this approach to make subsystem performance identifiable and testable so that revision efforts can be focused and productive. The annual improvements to retain of the operating subsystem of the Volkswagen are possible because the architecture of this useful artifact is explicit and subsystem performance can be observed and evaluated. Instructional design anticipates this same opportunity in connection with the activities listed in the second item in Figure 2.

Insert Figure 2 about here

It is noteworthy to consider the products of instructional design in more detail than is provided in Figure 2. A summary of the different audiences for which program documentation should be prepared is provided in Figure 3. The five columns on the right (headed by Roman numerals) refer to the headings in Figure 4, which is a more complete summary of design products than is found in Figure 2.

Insert Figure 3 about here

Insert Figure 4 about here

Examination of Figure 3 reveals that Category I, "Brochure Information," is useful for individuals at funding agencies, for production managers, and for colleagues and users. The needs and the goals are particularly needed for funding agencies. Curriculum development is an expensive business and, therefore, societal needs and institutional needs are written. Of these two needs, the one that effects design and justification with greater strength is the institutional need, summarizing a problem at a real educational or training installation. If training or education can be shown to be a solution to the problem, then goals of that need and objectives of these goals are developed. How to fund the project has to be determined, so societal needs are written. These are guided by the political priorities and interests of funding agencies. This should not be interpreted as a cynical remark. It is a fact of life that funding agencies want a linkage of research and development to one of the current political priorities. They also understand that the right things are not always done for the right reason. They know that there is no clear operational link between an institutional need and a societal need. They can make a class of institutions better if a funded program is a success whether or not all of the fortuitous or difficult events that lead to wide social acceptance occur.

The justification is a critical part of the design documentation, especially for CAI. Computers are just not appropriate for everything. In fact, at the present time (because of their cost), there is a rather limited range of functions their use is appropriate for, in a cost-effective way. A justification analysis must be undertaken to consider the advantages of computers, especially the unique advantages. Program development and administration must also be considered and compared with other methods. At the present time, there are many situations that justify computer-assisted instruction. The cost of labor-intensive instruction such as exists today under traditionally-administered instruction (TAI) is probably a linear function of time or perhaps a function increasing geometrically into the future. The cost of computers is on a decreasing curve. A graph could be constructed for each of a number of institutional needs, with an increasing line for TAI and a decreasing line for CAI. The two lines have crossed in chemistry and medical laboratories, certain areas in special education, and certain high-impact freshman courses; they have not crossed in history, certain aspects of the social sciences, and many, many other areas. However, for many areas within these fields, they will cross sometime in the future, perhaps sooner than anticipated.

Therefore, justification is basically an analysis of considerations of cost and effectiveness. Two basic categories of increased effectiveness result from computer usage:

(1) *Individualization is the primary reason for the existence of CAI.* With the help of CAI, the hypothetical individualized school, described earlier, can become a reality.

(2) *The computer brings something unique into the instructional situation.* It can execute algorithms very rapidly or simulate life-like environments with complex models, which cannot be accomplished by other forms of instruction.

These two categories permit the effectiveness justification to be written first and then the cost justification. As mentioned above, cost effectiveness analyses for CAI are premature; nevertheless, such analyses are demanded from time to time. Notice that although Harold Mitzel stressed the example of the horserace to show how premature such comparisons are, he also gave an analysis of the comparative costs of summer institutes versus vans carrying a portable CAI system.

Figure 4 contains more detail of the products of design and, hopefully, sheds some light on design activities, too. The following example illustrates each of the intermediate products of the design process. The first product, i.e., proposal or brochure information, consists of descriptions of societal and institutional needs. The example cited here is a dissertation recently completed in the CAI Lab by an interdisciplinary fellow. The student, Dr. Victorine Abboud (1970), is a very creative individual whose dissertation was a program to teach the Arabic writing system. She actually began with an institutional need discovered by her husband, Dr. Peter Abboud, who teaches the introductory Arabic course. He found that it required six weeks, working six hours per day, to teach writing to the students. If the audio-lingual approach is used, as the sounds pass in the air, students will invent their own notational scheme to recall these sounds. These idiosyncratic notations cannot be read by the teacher and be negatively transferred later. A notational scheme is developed because an adult learner, unlike a child, uses writing and note taking to learn. Since he primarily uses visual learning, he wants some written representation of the sounds. It thus becomes apparent that he should be given the actual Arabic characters. This is part of the institutional need. It would also be desirable to greatly shorten the six weeks it requires to learn the writing system. A number of students leave the course because they become bored if they do not encounter meaningful utterances for a long period of time.

Returning now from the institutional to some possible societal needs, it is noted that there are millions of people in the world who speak Arabic and try to write it. In addition, there is the Middle East crisis. This crisis poses a clear need for greater understanding among cultures. In addition, it points to the need for faster training of government and military personnel.

After the needs for such a course were determined, the goals were described. The *mastery model*, the major portion of a goal statement, was simple: Dr. Abboud wanted the student to be able to write--and write quickly--with the proper notation rather than with one that he invents. The prerequisites were also stated. The general description of approach (something that would be written in a brochure or to a funding agency) is that simultaneous, computer-coordinated use will be made of the graphic capabilities of a cathode ray tube, an image projector to display the written characters, an audiotape to provide the spoken equivalents simultaneously, and response by typing, light pen, writing on the CRT pad in a workbook, and vocalizing sounds.

Justification for the course was also provided. In a language learning situation, the classroom is only able to permit about six individual interactions per hour between teacher and student. With the computer, this can be multiplied by a factor of at least ten--there can be at least sixty interactions. There now is that factor of ten Heming was challenging us to produce. If it can indeed be shown that the interaction is one of the basic units in language learning, then our level of magnitude increase for this program can be achieved. Further justification comes from the ability to display Arabic characters on a cathode ray tube and to link them together from right to left. It is possible to develop some cost advantages because of the speed with which the objectives of this program can be accomplished, although Dr. Abboud did not stress cost aspects. A great deal of pleasure was received in evaluating this program when it was found that students required only four to eight hours at the computer plus four hours in the classroom for pronunciation, instead of the 36 hours and six weeks of classroom instruction previously required. Performance was significantly better on tests of writing and equally as good as sound discrimination (not an explicit objective of the program). Attitude was extremely positive toward the CAI program and there was no attrition.

The first step listed under "Design Architecture" in Figure 2 is to derive objectives from goals. The performance objectives were stated, and the analysis of objectives and the learning hierarchy was completed. As Category II in Figures 3 and 4 implies, these products are useful to an audience composed of professional colleagues. "Design Architecture" also allows transition to pedagogical theory and issues relative to some field. In this stage of the design process--the restructuring of a discipline--the decisive advances may be found, if they are to be found anywhere. It may also be found that it is possible by restructuring to enhance comprehension, and representations can be derived that are more powerful and economical for the human mind. The irrelevant can be identified and eliminated. This was done in the Arabic program. Instead of a random array of characters and sounds to be joined together or grouping by "similarity," Dr. Abboud performed a very careful analysis of subsets of Arabic letters which could combine to produce meaningful utterances. Four cycles were constructed such that, at the end of each, the student is speaking, reading, and writing meaningful utterances. The first cycle is built around a small set of meaningful words and phrases, the next cycle around a larger set, etc., so that by the end of four cycles, a considerable set of meaningful utterances is

available. To our knowledge, this approach has not been used in any other Arabic courses. It came about as a result of the behavioral analysis procedure.

Some Philosophical Considerations

Without going into the production steps of this example, departure is made from description at this juncture to consider something of the philosophy of science which instructional design implies. It differs from the usual approach of the social scientist in a way represented by Simon (1969) as the difference between an *artificial science* and a *natural science*. The natural scientist is concerned with learning about nature. He is interested in basic laws. For a hundred years, psychology has been trying to apply the natural science approach to human learning. Sigmund Koch (1969) claims that this hundred-year effort has demonstrated the failure of this approach. He may be right. The attitude of the artificial science approach is:

> *Human performance is probably conditional on so many factors that it's beyond our control to discover useful natural laws of learning; however, we can look at science as a systematic, empirical procedure for designing and testing artifacts which are useful to people and help people to be the way they* can *be or* ought *to be.*

A critical distinction between the ideas of natural and artificial sciences is that one deals with *can be's*, *oughts*, and *shoulds*, while the other deals with artificial science. Whether absolutes are truly a characteristic of a natural science is certainly debatable. There is no basis for this debate in an artificial science approach. In our design approach, it is not being claimed that our learning hierarchy is necessarily fundamental nor that our objectives and their relationships are fundamental discoveries about how people are and how behavioral repertoires exist in nature. What is being claimed is that our analysis may be a step forward in that it is more economical and powerful (to use Bruner's, 1966, terms) as a representation than was the analysis and representation of the structure of that discipline which previously existed. It is also hoped that other people, after examining our representation, can develop and design a new artifact which is even more powerful. This philosophy of the function of a learning hierarchy is fundamentally different from Gagné's conception (Gagné, 1968). This is where, in my opinion, decisive advances may come--through the restructuring of disciplines, the breaking down of disciplinary boundaries, and the perception of a common structure in subject matter across many fields. The design approach allows this to be done. It also enables and commands us to test ourselves along the way. We can be filled with enthusiasm, too, of the "Buckminster Fuller variety" that we are designing the environment (in this case the learning environment) to be better for people who freely choose to employ our artifacts.

An Emerging Discipline of Design

Return once more to the assertion that decisive advances can be achieved in education due to the cross-fertilization with computer science. Figure 5 lists areas from both computer science and psychology. It could also, with justification, list education or fields other than computer science, e.g., engineering, systems engineering, or even architecture. In these cases it would be found that Koestler's idea of cross-fertilization between fields is equally relevant. However, there are some specific implications of the thinking models and concepts of the computer scientist for the instructional designer and educational thinker. These can lead to a discipline which is referred to in Figure 5 as instructional software engineering (instructional design is also an adequate designation). There are at least two levels on which cross-fertilization can occur. One of them is metaphorical or analogical; the other is characterized by transferring a specific procedure from computer science to education or from psychology to computer science.

Insert Figure 5 about here

Examining the design model presented earlier, it is seen that the whole model is a metaphorical representation of system analysis. There are three concerns in system analysis:

(1) First, there is the context in which a system is to be built. The context of an instructional system is the institution as it is embedded in a society. The institutional needs and the societal needs emerge from this concern.

(2) System analysis also uses the "black box" approach of specifying input, output, and process, as when we write performance objectives, performance prerequisites, and then synthesize some instructional vehicle that will enable the student to transform his performance capability from input to output.

(3) Finally, system analysis features the use of feedback to modify and evolve our design products--improve the black box we have engineered--on the basis of experience.

The justification step in instructional design can perhaps be stimulated by a specific transfer from another field, namely optimization theory. The various costs of producing and operating a system and various effectiveness measures can be examined, and optimization theory can be used to determine whether or not use of a computer is a good idea in a specific application.

In the task analysis procedure, there is one of the most potent transfers at a metaphorical level from computer science to education. The

systems analyst has found there is a limit to the size and complexity of information structures that can be retained in the mind; therefore, it is very profitable to analyze step-by-step in a hierarchical fashion, solving one subproblem at a time before going on to the next. The ultimate solution is consistently postponed until the bottom is reached, and suddenly the whole problem has disappeared because it was done step-by-step.

This hierarchical analysis scheme used by the programmer is very potent in structuring educational material. It has helped to shed some light on the task analysis procedure that Gagné (1968) has presented. His statement is that, starting with a performance objective, one asks the question, *What must the learner do, given only instructions, to perform this objective?* In answer to this, one or more lower-order objectives are obtained. This process is repeated until a learning hierarchy is produced. It was found at the CAI Lab that this procedure is nonreproducible in that two people both performing the analysis independently will obtain quite different hierarchies. As a result, a system analysis procedure was attempted, describing the system as an algorithm. This can obviously be accomplished in much of science learning, math learning, and other structured subjects. Perhaps it can be done even in some aspects of language learning and other areas as well. Nonetheless, the approach taken is to draw a flowchart for an efficient method of performing the objectives. An attempt is then made to create the most efficient information-processing scheme possible on the model of an artificial intelligence analysis. Our concern will not be with natural science, whether or not our procedure is a simulation of the way people normally think. Instead, we will be concerned with the following question: *Can people learn to think that way?* Arriving at an information-processing or algorithmic analysis, it is divided into subobjectives on the basis of step-size considerations. This is an empirical question. The result is a task structure that is reproducible in the sense that the component steps can be given to programmers or other orderly-thinking people, and they will put them in the order that is the same as we think they should be, because of the logic of the algorithmic analysis.

Another example of metaphorical transfer is seen in relation to artificial intelligence. As the computer scientist's analysis of inductive reasoning or language is explored, he is seen to begin structuring the underlying processes in novel and very powerful ways. It may be possible to adapt these as structures for instruction.

Another concept that transfers from computer science to education is that of representation. This term is used rather loosely in education, being regarded as the media used to present information to the student. However, it is deeper and more powerful than this. In computer science the selection of representation is a critical step in solving a difficult problem; e.g., what kind of data structure should be established to represent the process of solving a checker program or of solving the missionary-cannibal problem? Computer scientists have shown that one representation is enormously more powerful for one problem than for another; e.g., perhaps

a certain matrix arrangement will allow solution of the missionary-cannibal problem in ten steps, whereas another representation might require a hundred steps. This same notion can be applied to human thinking. *Can representations be constructed that convey information and its relationships in a convenient manner and that permit people to manipulate them in a more convenient manner than current representations?* This notion is one reason for using some visual aids in an address such as this, since verbal strings audibly entering in a linear flow are not necessarily the most powerful representation that could be constructed for communicating ideas and demonstrating the interrelations between these ideas. To process these strings requires returning to the first of the verbal string and making many connections. People differ in their ability to accomplish this.

Finally, a specific technique that can be transferred from computer science is design automation. The programming-coding process can be automated, and programs can be written so that the only remaining task is to format materials in certain English language structures or tables. A keypunch operator can then punch the necessary cards which can then be submitted to a computer program. The program will eliminate the need for skilled CAI programming. Related transfer from computer science comes in the development of the author's manuscript. Instead of programming each display separately, the author can combine many displays into a subroutine, allowing one processing sequence to operate on a great host of data. For example, in a math learning system, a subroutine can be written which will generate exercises to specifications or from a table. The verbal text is written with variables at different places in the text. These variables can be inserted into the fixed displays to generate different problems. Instead of presenting one problem, forty can be generated if this would be of value to the student.

Many other things could be said about the cross-fertilization between computer science and education. These examples are provided to help justify the proposition that such cross-fertilization can lead to a decisive advance in instructional effectiveness.

Implications to Educators

As a final consideration, I would like to discuss the implications for colleges of education. When the model of individualized education, described earlier, is examined, the first implication is that colleges of education may not survive, certainly not in their present form. The new mode is an educational system rooted in the school which has a professional ladder for people to climb. People can initially be teacher aids (as they are called today) in one of the lower categories. After a couple of years of technical training, they can be proctors, librarians, computer operators, media specialists, or programmers. As they serve in this system, they are in the middle of a learning opportunity of their own. This enables them to observe how the managers, the librarian, and the instructional designer operate. If they are progressive (and if there is a built-in program in the

system to teach them, too), they might reach a point where they would like to become an instructional manager, to return to school to be trained as an instructional designer, or to become a master teacher if they prove to have the capabilities. An inservice teacher education program could thus, in a sense, be built into this system. Preservice education could be that of a good undergraduate liberal education, with the difference that the undergraduate systems would have more resemblance to the individualized schools, described earlier, than to the professor-dominated classroom of today.

The instructional designer, though, may not be at one particular school. If however, he is in a school, he may have a lower-order skill than other instructional designers. A brighter future is foreseen for graduate programs in the college of education than for teacher education programs. The future for teacher education programs apparently depends on the extent to which colleges of education themselves are willing to adopt instructional models which are individualized, self-paced, and systematic but personal. It is a truism that *teachers teach the way they were taught.* Unless we have an individualized computer-augmented, human-managed instructional system, students will continue to be produced who can perform only the lock-step variety of instruction. However, if teacher education programs are transformed to include other models, CAI can lead the way, becoming a forerunner in training students who will be able to function in new kinds of schools. If this is failed to be done, teacher education programs in the college of education will be replaced with something else.

One view of staffing requirements for a graduate school is summarized in Figure 6. In order to execute such an operation, a continual program of research and development is needed. It is not enough that computers in education are at a research and development state now; the basic philosophy of computers requires that systems continually be subject to development. Essentially, this means establishing an improvement loop. A program is first submitted, and then it is debugged. From its use, desirable additions are learned, so changes are inserted; once again, it is debugged and use is resumed: *It is a continual process of evolution.* The explicit and operational nature of the program makes improvement possible. Schools should be this way, too, and thus be linked to research and development by experienced and capable individuals at a graduate level.

Therefore, in a university or federally-funded center for development and research, there would be master degree programs for instructional designers and apprentice programs for the production technicians whom they supervise. This training would occur within the context of curriculum development efforts. Engineers are needed, and the disciplinary boundaries need to be broken down. Working with teachers, managers, and designers, the engineers would develop student interface devices to make them more economical, reliable, and flexible. Educational psychologists, computer

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Insert Figure 6 about here

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scientists, and others would supervise research assistants, the subtle difference being emphasis on design science rather than on a supposed natural science of human learning. Experts from disciplines in which curriculum packages are being designed must author the materials, assisted by instructional designers.

This outline of some roles in a graduate school and their relationship to individualized schools with differentiated staffing has been drawn too hastily. In spite of the brevity of this outline, however, we are each provided the opportunity to alter it, fill it out, and color it to individual preference. It is hoped that by the way positions were stated in this paper that some sense of arousal, if not of urgency, in this enterprise was conveyed, because when ideas behind computers are blended with ideas behind education, the result is a variety of compounds that possess great power and potential for both positive and negative consequences.

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1. INSTRUCTIONAL DESIGNERS

SUPERVISE

2. PRODUCTION TECHNICIANS
(MEDIA, PROGRAMMING)

3. MANAGERS OF INDIVIDUALIZED INSTRUCTION

SUPERVISE

4. OPERATIONS TECHNICIANS
(PROCTORS, LIBRARY, COMPUTER)

5. "MASTER" TEACHERS

Figure 1.--New Roles for "Teachers"

Activities	*Products*
1. Write needs, goals, and justification.	Proposal for Development Program Brochures
2. Develop design architecture and rationale. Objectives and Analysis Individualizing Mechanisms Display and Response Conventions	Objectives, analysis, flowcharts, and conventions to guide authoring. Documentation of research and pedagogical issues of theoretical interest.
3. Write author's draft.	Manuscript for production personnel.
4. Produce program. Media Debugged code	Technical documentation for installation, maintenance, and operation of program.
5. Conduct formative and summative evaluation.	Revision specifications and research studies.

Figure 2.--Outline of an Instructional Design Model.

Source	Product Categories				
	I	*II*	*III*	*IV*	*V*
1. Funding Agency	x				x
2. Production Manager	x				x
3. Production Personnel					
Target Computer System			x		
"Transplant" System			x	x	
4. Professional Colleagues	x	x			
5. Potential Users	x				
6. Customers	x	x		x	
7. Students				x	

Figure 3.--Audiences for CAI Program Documentation.

I. "Brochure" and Proposal Information

Societal Needs
Institutional Needs
Goals: "Mastery Model"; Prerequisites;
General Description of Approach and Justification;
Some Evaluative Data.

II. Design Architecture and Rationale

Performance Objectives
Analysis of Objectives and Learning Hierarchy
Synthesis of Course Structure and Restrictions
    Individualizing Mechanisms (flowcharts)
    Tests to Measure Objectives
    Specification of display and response conventions for each subordinate objective
Technical Evaluation and Research Reports

III. Manuscript or Author's Draft

Program Steps and Step Formats; Subroutines

IV. Technical Documentation for Final Program Components

Program Documentation for Systems Programmers
Documentation for Operations:
    Operator and Proctor Guides
Student Manuals

V. Production Management plans for the Production of All Procedures Listed Above.

Figure 4.--Documentation of Instructional Design

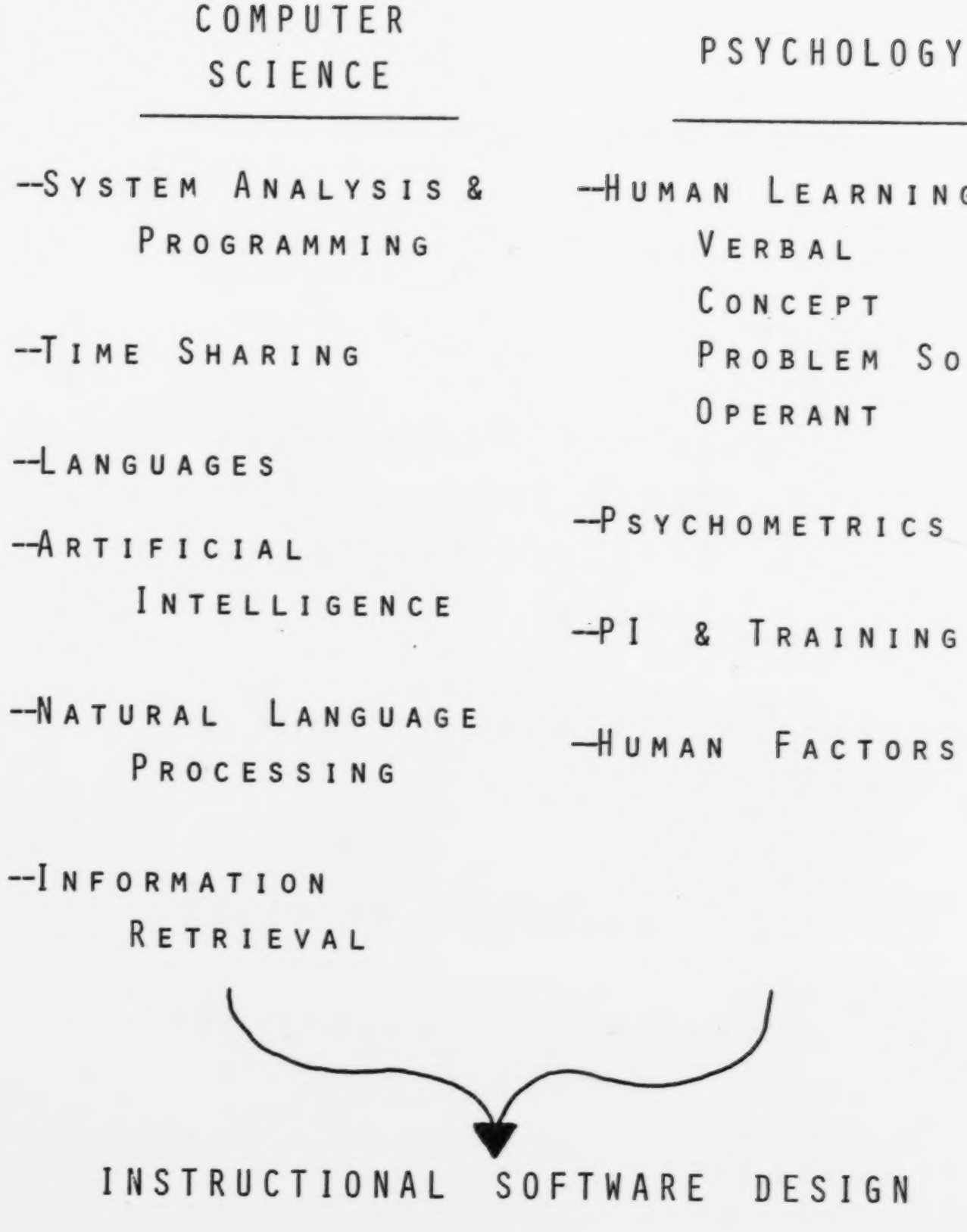
COMPUTER SCIENCE
--SYSTEM ANALYSIS & PROGRAMMING
--TIME SHARING
--LANGUAGES
--ARTIFICIAL INTELLIGENCE
--NATURAL LANGUAGE PROCESSING
--INFORMATION RETRIEVAL
PSYCHOLOGY
--HUMAN LEARNING:
VERBAL
CONCEPT
PROBLEM SOLVING
OPERANT
--PSYCHOMETRICS
--PI & TRAINING
--HUMAN FACTORS
INSTRUCTIONAL SOFTWARE DESIGN

Figure 5

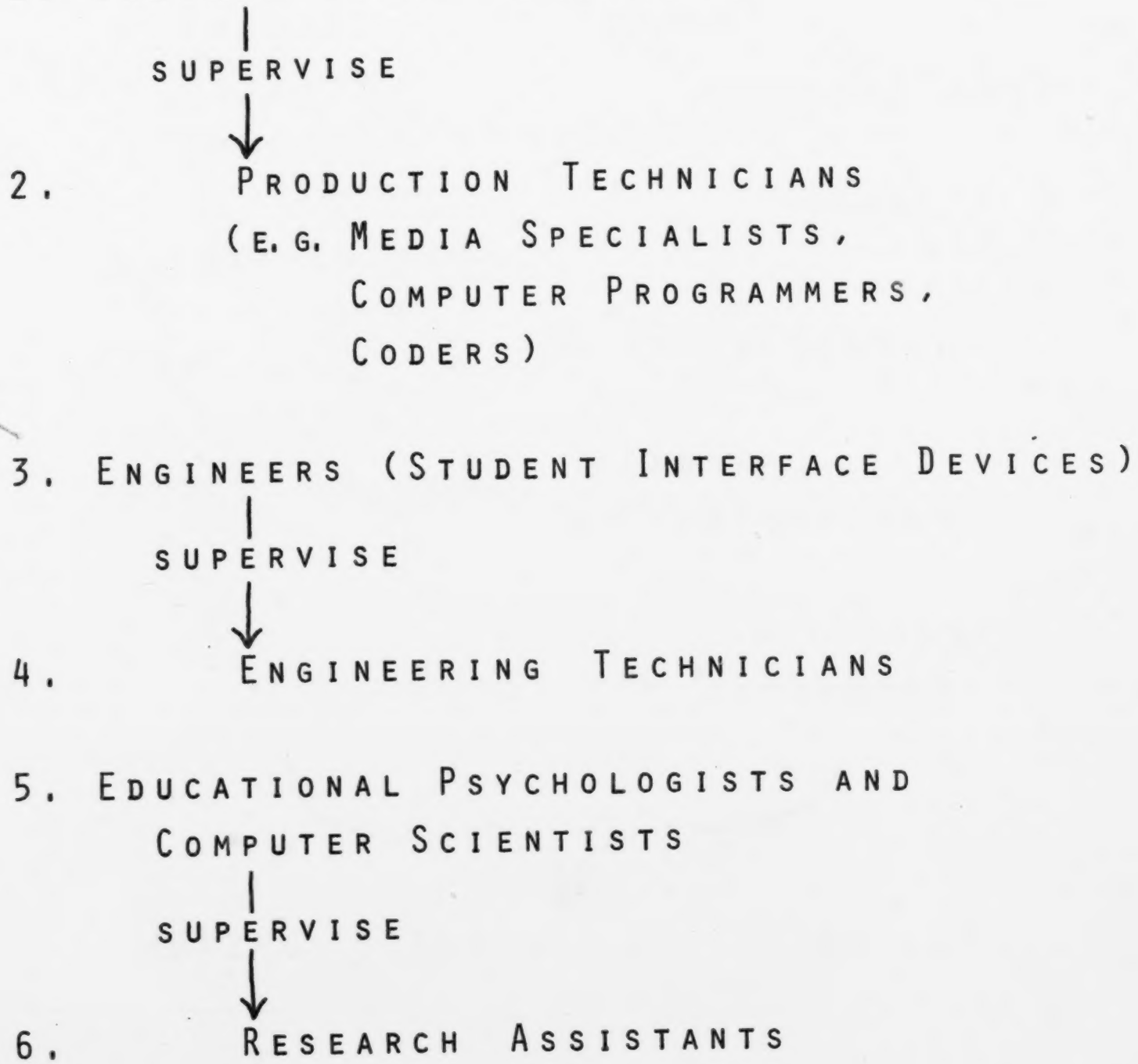

Figure 6.--New Education Professions in a Graduate School